JACC Vol. 32, No. 2
August 1998:345–52

Gender Differences in Use of Stress Testing and Coronary Heart Disease Mortality: A Population-Based Study in Olmsted County, Minnesota

VERONIQUE L. ROGER, MD, MPH, STEVEN J. JACOBSEN, MD, PHD, PATRICIA A. PELLIKKA, MD, FACC, TODD D. MILLER, MD, FACC, KENT R. BAILEY, PHD, BERNARD J. GERSH, MB, CHB, DPHIL, FACC*

Rochester, Minnesota and Washington D.C.

Objectives. **We sought to examine the utilization of exercise stress testing in relation to age and gender in a population-based setting.**

Background. **The utilization of noninvasive procedures has been shown to be associated with the subsequent use of invasive procedures. Yet, there are no population-based data on the utilization of stress testing; in particular, although gender differences in the use of invasive procedures have been reported, the use of noninvasive procedures has not been examined in relation to gender.**

Methods. **In Olmsted County, Minnesota, passive surveillance of the medical care of the community is provided through the Rochester Epidemiology Project. A population-based cohort of Olmsted County residents undergoing exercise tests was identified. The medical records of residents with prevalent and incident exercise tests in 1987 and 1988 were reviewed. For persons with an initial test (incidence cohort), data on clinical presentation, test indications and results were abstracted. Stress test utilization rates were calculated, and crude rates were directly adjusted to the age distribution of the 1980 U.S. population. To help interpret patterns of use at the population level, coronary heart disease mortality rates (International Classification of Diseases, 9th revision, codes 410 to 414) were calculated (crude and directly adjusted to the overall age distribution of the 1980 U.S. population) and used as an indicator of coronary disease burden.**

Results. **A total of 2,624 tests were performed. The crude utilization rate (per 100,000) was 1,888 for men and 703 for women (rate ratio for men over women 2.7, 95% confidence interval [CI] 2.5 to 2.9); it remained significantly higher in men across all age strata. The crude incidence rate (per 100,000) of initial stress tests was 1,112 for men and 517 for women (rate ratio 2.2, 95% CI 1.9 to 2.4). For both men and women, the incidence increased with age; however, incidence remained lower in women in all age strata. At the time that they underwent an initial test, women were more symptomatic and had poorer exercise performance than men. The rate ratio of men over women for coronary heart disease mortality was 1.1 (95% CI 0.9 to 1.2). The age-adjusted rate ratios for stress test utilization were 2.8 (95% CI 2.5 to 3.0), and that for coronary heart disease mortality was 1.9 (95% CI 1.7 to 2.2).**

Conclusions. **These population-based data show that during the study period, the utilization of stress testing in Olmsted County was lower in women than in men. Women in the incidence cohort were older and more symptomatic and had poorer exercise performance than men. Such differences should be considered when examining the utilization of subsequent invasive procedures according to gender.**

(J Am Coll Cardiol 1998;32:345–52)

Despite a dramatic decline in overall cardiovascular mortality (1,2), heart disease remains the leading cause of death for both men and women in the United States (3). Some reports (1,2) emphasize a slower rate of decline in mortality for women than in men. The decline in mortality appears to have been favorably influenced by the utilization of cardiovascular therapy (4), yet several studies have shown (5–10) that invasive cardiac procedures are used less frequently in women than in men. The exact role of gender as an independent determinant of variation in health care delivery remains the subject of a considerable controversy (10–15). There is some evidence that women are equally likely to undergo revascularization once they have undergone coronary angiography (6,16).

Thus, the determining point in the advent of gender differences in the delivery of cardiac care would appear to occur at an earlier phase in the sequence of care. Because the utilization of invasive cardiac procedures is strongly related to the use of stress test (17), it is crucial to examine the use of noninvasive cardiac procedures according to gender to help understand gender differences in the use of invasive proce-

From the Mayo Medical Center, Rochester, Minnesota, and *Georgetown University Medical Center, Washington, D.C. This study was supported in part by Grant in Aid 93-0132 50-02 from the American Heart Association National Center, Dallas, Texas and by Grant AR30582 from the Public Health Service, National Institute of Health, Bethesda, Maryland.

Manuscript received May 14, 1997; revised manuscript received April 10, 1998; accepted April 23, 1998.

Address for correspondence: Dr. Veronique L. Roger, Division of Cardiovascular Diseases, Mayo Clinic, 200 First Street SW, Rochester, Minnesota 55905. E-mail: roger.veronique@mayo.edu.

Published by Elsevier Science Inc.

0735-1097/98/$19.00
PII S0735-1097(98)00229-0

Abbreviations and Acronyms
ICD = International Classification of Diseases
CI = confidence interval

dures. Yet, comprehensive data on the use of stress testing at the population level have not been reported. To measure utilization rates, a population-based approach is needed. Examining this matter in a community setting has the added important advantage of avoiding the potential biases inherent to the studies of referral populations in tertiary care centers (18–21). The present study takes advantage of the resources of the Rochester Epidemiology Project to examine the utilization of stress testing in a population-based setting in all age groups and according to gender. It was designed to test the hypothesis that there was no gender difference in the utilization rates of stress testing in the population of Olmsted County Minnesota. To help interpret the health care delivery patterns observed, population-based mortality rates for coronary heart disease were examined.

Methods

Study setting and cohort design. Epidemiologic research in Olmsted County is possible because the county is relatively isolated from other urban centers, and nearly all medical care is delivered to local residents by a handful of providers. In 1990, census data indicated that the population was 96% white, with 28% of the population >45 years old and 11% ≥65 years old. With the exception of a higher proportion of the working population employed in the health care industry, the characteristics of the population of Olmsted County are similar to those of U.S. whites.

Virtually all the medical care received by the Olmsted County population is provided by the Mayo Clinic and the Olmsted Medical Group and its affiliated Olmsted Community Hospital. The epidemiologic potential of this situation is enhanced by the fact that each provider uses a unit medical record system, whereby all data collected for an individual subject are assembled in one place. Thus, the details of every inpatient and outpatient encounter can be accessed. The result is the linkage of medical records from all sources of medical care used by the Olmsted County population. These records are easily retrievable because the Mayo Clinic has maintained, since the early 1990s, extensive indexes based on clinical and histologic diagnoses and surgical and billable procedures (22,23).

The Rochester Epidemiology Project indexes, augmented by the log books of the laboratories performing stress tests, were used to identify a retrospective, population-based cohort of Olmsted County residents who underwent an exercise stress test between January 1, 1987 and December 31, 1988. This time frame corresponds to a period during which there was widespread and uniform use of a validated stress modality (i.e., exercise testing). Indeed, in Olmsted County during the time frame of the study (1987 and 1988), exercise was essentially the only stress modality in use: Only four dipyridamole stress tests were performed in 1987 and nine in 1988. Focusing on the time frame preceding the dispersion of stress tests modalities suppresses potential confounding of the gender differences in the use of exercise stress tests by the availability of other stress modalities. This time period allowed us to obtain coronary disease mortality surveillance data in the community studied. Finally, it provided the opportunity to analyze practice patterns before the publication of the majority of the reports generating concern over gender bias (6–10,13,24,25), precluding the influence of such publications.

Residency in Olmsted County in years 1987 and 1988 was verified using information from birth certificates and city and county directories. Residency on the index date and 1 year before the index date were determined to identify anyone from the cohort who may have moved to Olmsted County specifically to facilitate the diagnosis and treatment of conditions associated with a stress test. Analyses included all persons presenting for a stress test during the study period.

The prevalence cohort comprised all persons who underwent an exercise stress test during years 1987 and 1988. The incidence cohort comprised patients who underwent an *initial* exercise stress test in 1987 and 1988, as identified through the comprehensive review of the medical records. For these patients, data were collected to characterize patient demographics, presence, intensity, duration of clinical signs and symptoms, cardiovascular disease risk profile and comorbidity. Data collection was carried out by a team of two experienced nurse abstractors (V.L.R., S.J.J.) under direct supervision by the primary investigator of the study.

To ensure the consistency of the abstraction process, each abstractor reviewed independently the same sample of 20 records, and a sample of records already abstracted reviewed was reviewed again by the same abstractor. Agreement between the two reviews for both intraabstractor and interabstractor variability was measured using kappa coefficients. Variables yielding less than good agreement were entirely reviewed.

The indications for the initial stress test were classified as 1) *evaluation of documented coronary disease* defined by the presence of any of the following three criteria: history of myocardial infarction, coronary stenosis >50% by visual estimate on coronary angiography before the stress test or previous coronary revascularization procedure (coronary artery bypass graft surgery or angioplasty); 2) *diagnostic* if the patient had any symptoms (dyspnea or chest pain) and did no indication of documented coronary disease; and 3) *other* if performed in the absence of any symptoms and any documented coronary disease.

The stress tests (treadmill exercise test, exercise radionuclide angiography or exercise thallium scintigraphy) were considered positive according to conventional criteria, as previously reported. (26)

The existence of any comorbid condition was determined

Table 1. Utilization* of Stress Tests in Olmsted County, Minnesota, 1987 to 1988

Age (yr)	Women			Men			Men/Women Rate Ratio (95 CI)	p Value
	No. of Stress Tests	Population	Rate (95% CI)	No. of Stress Tests	Population	Rate (95% CI)		
0–19	0	31,454	0 (0–0)	8	32,447	25 (8–42)		0.0080
20–29	42	18,548	226 (158–295)	71	16,645	427 (328–526)	1.9 (1.3–2.8)	0.0009
30–39	99	18,734	528 (425–638)	312	18,352	1,700 (1,513–1,889)	3.2 (2.6–4.0)	< 0.0001
40–49	133	12,787	1,040 (867–1,216)	430	12,426	3,460 (3,139–3,782)	3.3 (2.8–4.1)	< 0.0001
50–59	156	8,689	1,795 (1,516–2,075)	480	8,718	5,506 (5,027–5,985)	3.1 (2.6–3.7)	< 0.0001
60–69	177	6,763	2,617 (2,237–2,998)	386	5,871	6,575 (5,941–7,209)	2.5 (2.1–3.0)	< 0.0001
70–79	113	5,322	2,123 (1,736–2,511)	161	3,403	4,731 (4,018–5,444)	2.2 (1.8–2.8)	< 0.0001
80+	28	4,041	693 (437–969)	28	1,508	1,857 (1,175–2,538)	2.7 (1.6–4.5)	< 0.0001
Total	748	106,338	703 (653–754)	1876	99,370	1,888 (1,803–1,973)	2.7 (2.5–2.9)	< 0.0001

*Includes all stress tests performed among local residents; each person was considered to be at risk. CI = confidence interval.

through comprehensive review of the medical record. Comorbidities were recorded individually and were combined in a validated summary measure of comorbidity (the Charlson index [27]). The Charlson index is a weighted index of comorbidity that assigns weights for each condition present in a given patient. This index has been used in studies based on medical record review such as the present study and has also been adapted for use with administrative databases (28). It is strongly related to mortality independent of age.

Coronary heart disease mortality. To provide a benchmark to assist in the interpretation of the observed population-based rates of utilization of stress testing, coronary heart disease mortality rates in Olmsted County were used as a measure of the coronary disease burden at the population level. Death tapes containing death certificate data from the Minnesota Department of Health were obtained for Olmsted County residents for years 1987 through 1993. The codes from the ninth revision of the International Classification of Diseases (ICD) that were used as indicators of coronary heart disease mortality were as follows: 410 (acute myocardial infarction), 411 (other acute or subacute coronary heart disease), 412 (old myocardial infarction), 413 (angina) and 414 (other forms of chronic ischemic heart disease). These are the traditional codes used in community surveillance studies (29).

Statistical analysis. *Use of exercise stress tests.* Utilization and incidence rates were calculated as the numbers of exercise stress tests divided by the Olmsted County population in 1987 and 1988 as derived by linear interpolation of census figures for 1980 and 1990 (30). The entire population of Olmsted County was considered to be at risk for utilization rates. For incidence rates, patients who had undergone stress testing before the study period were no longer at risk for an incident test and thus were removed from the denominators. Overall and age- and gender-specific rates of use of exercise stress tests were calculated. The threshold of 65 years was also used to stratify the rates. This stratification was performed to compare informally the utilization of stress tests in Olmsted County with published Medicare data. Confidence intervals around the point estimates were calculated assuming a Poisson error distribution. The rates were directly adjusted to the age distribution of the 1980 U.S. total population.

Among incident cases, comparisons between men and women were made for a number of characteristics: age, cardiovascular risk factors, clinical presentation at the time of the initial stress tests and results of the stress test. The frequencies of specific comorbid conditions were compared across genders individually and combined using the Charlson index. Bivariate associations with gender were tested with chi-square tests for categoric data and *t* tests for continuous variables.

Coronary heart disease mortality rates. Annual mortality rates were calculated using coronary deaths as numerators; the denominators were the Olmsted County population as derived by linear interpolation of census figures for 1980 and 1990 (30).

Age- and gender-specific mortality rates were calculated. The crude rates were directly adjusted using the 1980 U.S. total population as the standard. Confidence intervals around the point estimates were calculated assuming a Poisson error distribution.

Results

Utilization. In 1987 and 1988, a total of 2,624 stress tests were performed. The crude rate for men was 1,888/100,000, and that for women was 703/100,000. The crude rate ratio for men over women was 2.7 (95% confidence interval [CI] 2.5 to 2.9, $p < 0.0001$).

The age-specific utilization rates are displayed in Table 1. The utilization rates were higher for men than women in all age groups. With increasing age, the utilization rate ratios of men to women tended to diminish, but exercise stress tests were used nearly twice as frequently in men than in women across all age strata. Among persons ≥65 years old, the utilization rates were 1,699/100,000 (95% CI 1,473 to 1,925) for women and 4,803/100,000 (95% CI 4,322 to 5,284) for men; the rate ratio of men to women was 2.8 (95% CI 2.4 to 3.4, $p < 0.0001$).

After adjustment, the utilization rates of stress tests were 2,068/100,000 (95% CI 1,971 to 2,165) for men and 746/100,000 for women (95% CI 692 to 801). The age-adjusted rate ratio was 2.8 (95% CI 2.5 to 3.0, $p < 0.0001$). Among persons ≥65

Table 2. Incidence of Stress Tests in Olmsted County, Minnesota, 1987 to 1988

Age (yr)	Women			Men			Men/Women Rate Ratio (95% CI)	p Value
	N	Population	Rate (95% CI)	N	Population	Rate (95% CI)		
0–19	0	31,448	0 (0–0)	8	32,440	25 (8–42)		0.0080
20–29	40	18,481	216 (149–283)	68	16,582	410 (313–507)	1.9 (1.3–2.8)	0.0011
30–39	90	18,483	487 (387–587)	267	18,006	1,483 (1,306–1,659)	3.1 (2.4–3.9)	< 0.0001
40–49	108	12,492	865 (702–1,027)	280	11,694	2,394 (2,117–2,671)	2.8 (2.2–3.5)	< 0.0001
50–59	105	8,311	1,263 (1,023–1,504)	214	7,844	2,728 (2,368–3,089)	2.2 (1.7–2.7)	< 0.0001
60–69	110	6,385	1,723 (1,404–2,042)	156	5,124	3,044 (2,574–3,515)	1.8 (1.4–2.3)	< 0.0001
70–79	69	5,044	1,368 (1,047–1,689)	61	3,044	2,084 (1,506–2,502)	1.5 (1.0–2.1)	0.0276
80+	19	3,990	476 (263–690)	16	1,447	1,106 (567–1,645)	2.3 (1.2–4.5)	0.0103
Total	541	104,634	517 (474–560)	1,070	96,181	1,112 (1,046–1,179)	2.2 (1.9–2.4)	< 0.0001

CI = confidence interval.

years old, the age-adjusted rate ratio was 2.5 (95% CI 2.1 to 3.0).

Incidence. In 1987 and 1988, a total of 1,611 initial stress tests were performed in 541 women and 1,070 men. The crude rates for initial stress test were 1,112/100,000 for men and 517/100,000 for women. The corresponding crude rate ratio for men over women was 2.2 (95% CI 1.9 to 2.4, $p < 0.0001$).

The age-specific incidence rates by gender are displayed in Table 2. For both women and men, the incidence rates peaked between ages 60 to 69 years, corresponding to 3% of the male population and 1.7% of the female population in this age stratum. The incidence rates were markedly higher in men in all age groups, with the difference being statistically significant in all strata.

After adjustment, the rate for men was 1,191/100,000 (95% CI 1,116 to 1,266) and 548/100,000 (95% CI 501 to 595) for women. The age-adjusted rate ratio was 2.2 (95% CI 2.0 to 2.4, $p < 0.0001$).

Incidence cohort. *Baseline characteristics.* The baseline characteristics among incident cases are summarized in Table 3. Women were older, more likely to be symptomatic (64% of women reported either chest pain of dyspnea on exertion vs. 53% of men, $p = 0.001$) and had a greater frequency of typical as well as atypical chest pain. Consistent with this symptom status, they were also more likely to be taking antianginal medication. They were less likely to be smokers but more likely to be hypertensive. The body mass index was greater in men than in women. The frequency of diabetes mellitus was 4% in both men and women. Women and men were equally likely to have a history of myocardial infarction or heart failure. Women were more likely to have peripheral or cerebrovascular disease, but the magnitude of these differences was small. However, there was no gender difference in the Charlson index, which is a summary measure of comorbidities. Age stratification did not reveal any gender difference in the Charlson index.

Indications and results of the stress test. For both men and women, the vast majority of the stress tests were treadmill exercise tests, which reflects the practice in our community during the study period. The indications for the exercise stress test are summarized in Table 4. More women underwent stress testing for diagnostic indications. With regard to exercise performance, men exercised longer than women and to a higher workload. They achieved a higher heart rate and systolic blood pressure with exercise, resulting in a higher peak rate–pressure product than women. These differences persisted after stratification by age. There was a similar percentage of positive tests in men and women.

Coronary heart disease mortality. The age- and gender-specific coronary heart disease mortality rates for the Olmsted County population in years 1987 through 1993 are shown in

Table 3. Baseline Characteristics of Persons With an Incident Stress Test, Olmsted County, Minnesota, 1987 to 1988, by Gender

Characteristic	Men (n = 1,070)	Women (n = 541)	p Value
Age (yr)	48 ± 14	53 ± 16	< 0.0001
Symptoms			
NYHA class III/IV	96 (9)	70 (13)	0.33
Typical angina	97 (9)	73 (14)	0.006
Atypical angina	144 (14)	118 (122)	0.001
Risk factors			
Hx of smoking	564 (53)	213 (39)	0.001
Diabetes mellitus	45 (4)	23 (4)	0.97
Hypertension	253 (24)	157 (29)	0.019
Hyperlipidemia	518 (48)	281 (52)	0.18
Family Hx of CAD	434 (42)	244 (45)	0.2
Other clinical factors			
BMI (kg/m^2)	27.4 ± 4.0	26.5 ± 6	< 0.0001
Hx of MI	111 (10)	44 (8)	0.15
Hx of CHF	23 (2)	15 (3)	0.43
Hx of CABG/PTCA	88 (8)	25 (5)	0.007
PVD	40 (4)	30 (6)	0.09
CVD	16 (2)	19 (4)	0.009
Charlson index	0.49 ± 1.15	0.59 ± 1.21	0.16
Medication use			
Antianginal agents	237 (22)	157 (29)	0.004
Estrogen replacement	0	94 (17.4)	—

Data presented are mean value ± SD or number (%) of patients. BMI = body mass index; CABG = coronary artery bypass grafting surgery; CAD = coronary artery disease; CHF = congestive heart failure; CVD = cerebrovascular disease; Hx = history; MI = myocardial infarction; NYHA = New York Heart Association; PTCA = percutaneous transluminal coronary angioplasty; PVD = peripheral vascular disease.

Table 4. Indications and Stress Test Results in Persons With an Incident Stress Test, Olmsted County, Minnesota, 1987 to 1988, by Gender

	Men (n = 1,070)	Women (n = 541)	p Value
Indication for ex stress test			< 0.001
Diagnostic	40%	54%	
Documented CAD	14%	10%	
Other	46%	36%	
Type of ex stress test			0.008
Treadmill	83%	77%	
RNA	12%	15%	
Thallium	5%	8%	
Ex stress test results			
Duration of ex test (min)	11.7 ± 4.1	9.4 ± 4.3	< 0.001
Workload (METs)	10.4 ± 3.7	8.03 ± 3.3	< 0.001
Peak HR (beats/min)	159 ± 28	153 ± 28	0.0056
Ex SBP (mm Hg)	183 ± 26	169 ± 26	< 0.001
Peak RPP (beats/min × mm Hg)	20,607 ± 4,173	19,330 ± 3,602	< 0.001
Positive test	12%	16%	0.139

Data presented are mean value ± SD or percent of patients. Ex = exercise; HR = heart rate; METs = metabolic equivalents; MI = myocardial infarction; RNA = radionuclide angiography; RPP = rate–pressure product; SBP = systolic blood pressure.

Table 5. The crude rate was 143/100,000 for men and 132/100,000 for women. The corresponding crude rate ratio was 1.1 (95% CI 0.9 to 1.2, p = 0.21).

The age-adjusted rate was 197/100,000 (95% CI 180 to 214) for men and 103/100,000 (95% CI 93 to 112) for women. The age-adjusted rate ratio was 1.9 (95% CI 1.7 to 2.2).

Among persons ≥65 years old, the coronary heart disease mortality rates were 975/100,000 (95% CI 885 to 1,065) for women and 1,428/100,000 (95% CI 1,290 to 1,567) for men. The crude rate ratio of men over women was 1.5 (95% CI 1.3 to 1.7, p < 0.0005), and the age-adjusted rate ratio was 2.0 (1.7 to 2.3).

Discussion

Gender differences in utilization of stress testing. To our knowledge, the present study is the first to report age- and gender-specific population-based rates of utilization of stress testing. In addition, incidence rates (i.e., first-time use of a stress test), which are useful to better understand the delivery of care in the earlier phase of the patient evaluation, are presented. During the study period, there was uniform use of a single, well validated stress modality; our data therefore represent the comprehensive experience of the community during that time frame. Age-specific rates indicate that utilization of stress tests increased with age to peak use in age group 60 to 69 years and declined thereafter. Although stress test use is intuitively perceived as being related to age, no data have been published to support this perception, and no gender-specific analysis of stress test use has been carried out, thus not allowing for gender differences, if any, to emerge (17).

Gender-specific analyses reported in the present study document, in a population-based setting, gender differences in the utilization of exercise stress tests. After adjustment, exercise stress tests were used almost three times as frequently in men than in women, and the age-adjusted rate ratio of men over women was highly significant. Because on average, coronary disease affects women later in the course of their lives than men, examination of utilization rates specific to older age strata is also needed. Among persons ≥65 old, the time at which detection of coronary disease is as clinically relevant a question in women as in men, the overall utilization of stress testing in men was still more than twice that in women. Age adjustment within the 65 years and above strata only marginally attenuated these gender differences.

Among persons in the incidence cohort, there were several important differences between men and women. Consistent with older age at onset of coronary disease (31,32), women were older and were more likely to present with typical angina. In addition, they had poorer exercise performance. Interestingly, despite their more advanced age, their Charlson index was not higher than that of men. Thus, among men and women

Table 5. Coronary Disease (International Classification of Diseases, 9th revision codes 410 to 414) Mortality Rates for Olmsted County Residents for Years 1987 to 1993

Age (yr)	Women			Men			Men/Women Rate Ratio (95% CI)	p Value
	N	Population	Rate (95% CI)	N	Population	Rate (95% CI)		
0–19	17	111,714	15 (8–22)	2	115,894	2 (0–4)	0.1 (0.0–0.4)	0.004
20–29	0	61,913	0 (0–0)	2	56,309	4 (0–8)		
30–39	0	69,818	0 (0–0)	4	69,064	6 (0–11)		
40–49	5	48,696	10 (1–19)	14	47,176	30 (14–45)	2.9 (1.1–8.5)	0.03
50–59	8	32,226	25 (8–42)	51	32,510	157 (114–200)	6.3 (3.2–14.0)	< 0.0001
60–69	55	24,273	227 (167–286)	102	21,626	472 (380–563)	2.1 (1.5–2.9)	< 0.0001
70–79	105	19,150	548 (444–653)	153	12,676	1,207 (1,017–1,397)	2.2 (1.7–2.8)	< 0.0001
80+	315	15,193	2,073 (1,847–2,300)	187	5,683	3,291 (2,827–3,754)	1.6 (1.3–1.9)	< 0.0001
Total	505	382,983	132 (120–143)	515	360,938	143 (130–155)	1.1 (0.9–1.2)	0.21

CI = confidence interval.

entering one major access pathway leading to invasive cardiac evaluation, there is no measurable difference in comorbidity despite older age, but women present with more symptoms than men and use more medications.

Appropriateness of use of stress testing. The differential use of stress testing between men and women observed in this population-based setting raises the difficult question of its appropriateness. Several points may be brought forth as a potential explanation for such observed differences: 1) Uncertainties about the diagnostic value of stress test in women, which have been amply documented in published reports (33–44) may account for part of these differences. It is of interest to observe that in a population-based setting, when women do undergo their first stress test, they have poorer exercise performance than men. This poorer performance may contribute to the lesser effectiveness of stress testing as a clinical diagnostic tool in women. 2) One could speculate that differences in access to health care between men and women could contribute to such differences. This difference cannot be totally excluded but is unlikely in a community where the majority of persons have insurance coverage (45,46). 3) Gender differences in the burden of disease evaluated with stress testing could play a role in such differences in test utilization. To address this question, a measure of the burden of coronary heart disease at the population level is needed. Although there is a general consensus that such burden differs according to gender, the exact difference between men and women with regard to the morbidity of coronary disease is actually difficult to measure, particularly in an aging population (47). Myocardial infarction incidence data, which are one source of such information, are rare in published reports (48,49), and most of the community surveillance programs that are designed to provide reliable incidence data have an upper age limit of 74 years (4,50,51). This truncates the description of the disease experience in women because coronary disease develops ~10 years later in women then in men. Cohort studies, including population-based studies carried in Olmsted County, that capture outpatient data have emphasized the difficulties with regard to the definition of coronary disease in women because of misclassification of chest pain, which is frequent in women but may not represent ischemia (31,32,52).

Thus, coronary disease mortality emerges as one of the few, albeit imperfect, resources to examine gender differences in coronary disease experience. Although such comparisons can only be informal, age-specific incidence rate ratios for stress testing (Table 2) are lower than those for coronary heart disease mortality (Table 5) across all age categories except for age 80 and above. Age-specific coronary heart disease mortality figures from the Olmsted County population (Table 5) clearly show that the coronary heart disease mortality difference between men and women greatly narrows with increasing age.

The unadjusted analyses describe the experience of men and women with regard to stress test use and coronary disease mortality over their lifetimes. The crude (total) rates show a disparity between genders in this regard. Whether this disparity reflects the greater age at which women experience coronary disease, which in turn may lead to a lesser ability to exercise, can only be speculative at this point and deserves further study.

Adjustment of the utilization and coronary mortality rates to the overall age distribution of the same population (U.S. 1980) also documented a greater disparity between genders in the use of stress tests than that observed in coronary disease mortality.

Thus, both crude and adjusted analyses indicate gender inequality in the utilization of stress tests. Whether this inequality reflects appropriate use, overutilization of stress testing in men or underutilization in women is uncertain because coronary disease mortality rates are an imperfect benchmark. Future studies analyzing secular trends in coronary disease incidence in relation to time trends in health care delivery in the same population are needed to further explore this issue.

Implications of lower use of stress testing in women. Regardless of the interpretation of the health care delivery patterns documented herein, such differences in stress test utilization are important for the understanding of the use of other downstream procedures. A strong association between the intensity of diagnostic tests and the subsequent use of invasive procedures has recently been reported (17,53). However, the intensity of the use of stress testing has not been examined according to gender. Although published studies present discordant results on the independent role of gender as a predictor of health care delivery, there is some evidence that once coronary anatomy is defined after coronary angiography, gender does not play an independent role in the management of patients (6,16).

This observation in turn prompts the question of the existence of gender differences in utilization of stress tests, a noninvasive procedure that often precedes coronary angiography and is an important determinant of subsequent cardiac care. Our data show gender differences in the use of stress testing that persist after age adjustment. This finding supports the assumption that gender differences in the use of stress tests may play a role in the genesis of documented gender differences in the use of coronary angiography (5,6,9,10). This assumption underscores the importance of examining the use of stress tests as part of the analysis of the use of "downstream" procedures when examining gender-specific delivery of cardiac care.

Limitations of the study. One potential barrier to the generalizability of these data is the pattern of health care delivery in Olmsted County, which may not be representative of the practice in other areas in the United States. However, recent data on the use of stress tests in Medicare beneficiaries from northern New England (17) indicated an annual utilization rate of ~4% in 1992 and 1993, which is comparable to the present data for men in this age category. In addition, the main objective of the present study was to evaluate gender differences in health care delivery, and although regional variations in health care delivery have been documented, there is no

plausible reason to believe that the practice in Olmsted County differs from other centers with regard to gender-specific patterns of care. Because these data are population based and are not subject to many of the referral or selection biases (18–21), it may be possible to generalize these findings to populations with a similar ethnic composition and socioeconomic status. It is noteworthy that the access to health care that residents of Olmsted County experience eliminates confounding due to barriers to health care access, which is important in an analysis of health care delivery.

Further studies in populations of different ethnic composition and socioeconomic status are needed to complement the present one.

Conclusions. The present population-based data indicate that the overall utilization of exercise stress tests in Olmsted County, Minnesota, in 1987 and 1988 was higher in men than in women. At the time that they underwent an initial test, women were more symptomatic and had poorer exercise performance than men. These differences should be considered when examining the utilization of subsequent invasive procedures according to gender.

We acknowledge the dedicated help of Jeannie Hill and Susan Stotz for data collection, Jill Killian for statistical analysis and Kristie Shorter for preparation of the manuscript.

References

1. Gillum RF. Trends in acute myocardial infarction and coronary heart disease death in the United States. J Am Coll Cardiol 1994;23:1273–7.
2. Sempos C, Cooper R, Kovar MG, McMillen M. Divergence of the recent trends in coronary mortality for the four major race-sex groups in the United States. Am J Public Health 1988;78:1422–7.
3. Gardner P, Hudson BL. Advance Report of Final Mortality Statistics, 1993. Monthly Vital Statistic Report. Hyattsville (MD): National Center for Health Statistics, 1996, vol 44.
4. McGovern PG, Pankow JS, Shahar E, et al. Recent trends in acute coronary heart disease—mortality, morbidity, medical care, and risk factors (the Minnesota Heart Survey Investigators). N Engl J Med 1996;334:884–90.
5. Tobin JN, Wassertheil-Smoller S, Wexler JP, et al. Sex bias in considering coronary bypass surgery. Ann Intern Med 1987;107:19–25.
6. Steingart RM, Packer M, Hamm P, et al. Sex differences in the management of coronary artery disease (Survival and Ventricular Enlargement Investigators). N Engl J Med 1991;325:226–30.
7. Khan SS, Nessim S, Gray R, Czer LS, Chaux A, Matloff J. Increased mortality of women in coronary artery bypass surgery: evidence for referral bias. Ann Intern Med 1990;112:561–7.
8. Maynard C, Litwin PE, Martin JS, Weaver WD. Gender differences in the treatment and outcome of acute myocardial infarction: results from the Myocardial Infarction Triage and Intervention Registry. Arch Intern Med 1992;152:972–6.
9. Ayanian JZ, Epstein AM. Differences in the use of procedures between women and men hospitalized for coronary heart disease. N Engl J Med 1991;325:221–5.
10. Shaw LJ, Miller DD, Romeis JC, Kargl D, Younis LT, Chaitman BR. Gender differences in the noninvasive evaluation and management of patients with suspected coronary artery disease. Ann Intern Med 1994;120:559–66.
11. Healy B. The Yentl syndrome. N Engl J Med 1991;325:274–6.
12. Wenger NK. Gender, coronary artery disease, and coronary bypass surgery. Ann Intern Med 1990;112:557–8.
13. Mark DB, Shaw LK, DeLong ER, Califf RM, Pryor DB. Absence of sex bias in the referral of patients for cardiac catheterization. N Engl J Med 1994;330:1101–6.
14. Hachamovitch R, Berman DS, Kiat H, et al. Gender-related differences in clinical management after exercise nuclear testing. J Am Coll Cardiol 1995;26:1457–64.
15. Lauer MS, Pashkow FJ, Snader CE, Harvey SA, Thomas JD, Marwick TH. Gender and referral for coronary angiography after treadmill thallium testing. Am J Cardiol 1996;78:278–83.
16. Bell MR, Berger PB, Holmes DR Jr, Mullany CJ, Bailey KR, Gersh BJ. Referral for coronary artery revascularization procedures after diagnostic coronary angiography: evidence for gender bias? J Am Coll Cardiol 1995;25:1650–5.
17. Wennberg DE, Kellett MA, Dickens JD, Malenka DJ, Keilson LM, Keller RB. The association between local diagnostic testing intensity and invasive cardiac procedures. JAMA 1996;275:1161–4.
18. Melton LJ. Selection bias in the referral of patients and the natural history of surgical conditions. Mayo Clin Proc 1985;60:880–5.
19. Warner MA, Hosking MP, Lobdell CM, Offord KP, Melton LJ. Effects of referral bias on surgical outcomes: a population-based study of surgical patients 90 years of age or older. Mayo Clin Proc 1990;65:1185–91.
20. Schneider AJ, Derr J. Referral bias in elderly patients [editorial]. Mayo Clin Proc 1990;65:1272–3.
21. Salive ME. Referral bias in tertiary care: the utility of clinical epidemiology [editorial]. Mayo Clin Proc 1994;69:808–9.
22. Kurland LT, Molgaard CA. The patient record in epidemiology. Sci Am 1981;245:54–63.
23. Kurland LT, Elveback LR, Nobrega FT. Population studies in Rochester and Olmsted County, Minnesota, 1900–1968. In: Kessler II, Levin ML, editors. The Community as an Epidemiologic Laboratory: A Casebook of Community Studies. Baltimore (MD): Johns Hopkins Press, 1970:47–70.
24. Bickell NA, Pieper KS, Lee KL, et al. Referral patterns for coronary artery disease treatment: gender bias or good clinical judgment? Ann Intern Med 1992;116:791–7.
25. Krumholz HM, Douglas PS, Lauer MS, Pasternak RC. Selection of patients for coronary angiography and coronary revascularization early after myocardial infarction: is there evidence for a gender bias? Ann Intern Med 1992;116:785–90.
26. The Mayo Clinic Working Group on Stress Testing. Cardiovascular stress testing: a description of the different types of stress tests and indications for their use. Mayo Clin Proc 1996;71:43–52.
27. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–83.
28. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45:613–9.
29. Thom TJ, Maurer J. Time trends for coronary heart disease mortality and morbidity. In: Higgins MW, Luepker RV, editors. Trends in Coronary Heart Disease Mortality: The Influence of Medical Care. New York: Oxford Univ Press, 1988:7–15.
30. Bergstrahl EJ, Offord KP, Chu C-P, Beard CM, O'Fallon WM, Melton L Jr. Calculating Incidence, Prevalence and Mortality Rates for Olmsted County, Minnesota Residents: An Update. Rochester (MN): Mayo Clinic, 1992.
31. Lerner DJ, Kannel WB. Patterns of coronary heart disease morbidity and mortality in the sexes: a 26-year follow-up of the Framingham population. Am Heart J 1986;111:383–90.
32. Murabito JM, Evans JC, Larson MG, Levy D. Prognosis after the onset of coronary heart disease: an investigation of differences in outcome between the sexes according to initial coronary disease presentation. Circulation 1993;88:2548–55.
33. Weiner DA, Ryan TJ, McCabe CH, et al. Exercise stress testing: correlations among history of angina, ST-segment response and prevalence of coronary-artery disease in the country artery surgery study (CASS). N Engl J Med 1979;301:230–5.
34. Sketch MH, Mohiuddin SM, Lynch JD, Zencka AE, Runco V. Significant sex differences in the correlation of electrocardiographic exercise testing and coronary arteriograms. Am J Cardiol 1975;36:169–73.
35. Hung J, Chaitman BR, Lam J, et al. Noninvasive diagnostic test choices for the evaluation of coronary artery disease in women: a multivariate comparison of cardiac fluoroscopy, exercise electrocardiography and exercise thallium myocardial perfusion scintigraphy. J Am Coll Cardiol 1984;4:8–16.
36. Detry JM, Kapita BM, Cosyns J, Sottiaux B, Brasseur LA, Rousseau MF.

Diagnostic value of history and maximal exercise electrocardiography in men and women suspected of coronary heart disease. Circulation 1977;56:756–61.
37. Guiteras P, Chaitman BR, Waters DD, et al. Diagnostic accuracy of exercise ECG lead systems in clinical subsets of women. Circulation 1982;65:1465–74.
38. Bruce RA, Hossack KF, DeRouen TA, Hofer V. Enhanced risk assessment for primary coronary heart disease events by maximal exercise testing: 10 years' experience of Seattle Heart Watch. J Am Coll Cardiol 1983;2:565–73.
39. Barolsky SM, Gilbert CA, Faruqui A, Nutter DO, Schlant RC. Differences in electrocardiographic response to exercise of women and men: a non-Bayesian factor. Circulation 1979;60:1021–7.
40. Friedman TD, Greene AC, Iskandrian AS, Hakki AH, Kane SA, Segal BL. Exercise thallium-201 myocardial scintigraphy in women: correlation with coronary arteriography. Am J Cardiol 1982;49:1632–7.
41. Melin JA, Wijns W, Vanbutsele RJ, et al. Alternative diagnostic strategies for coronary artery disease in women: demonstration of the usefulness and efficiency of probability analysis. Circulation 1985;71:535–42.
42. Hanley PC, Zinsmeister AR, Clements IP, Bove AA, Brown ML, Gibbons RJ. Gender-related differences in cardiac response to supine exercise assessed by radionuclide angiography. J Am Coll Cardiol 1989;13:624–9.
43. Hlatky MA, Pryor DB, Harrell F Jr., Califf RM, Mark DB, Rosati RA. Factors affecting sensitivity and specificity of exercise electrocardiography. Multivariable analysis. American J Med 1984;77:64–71.
44. Roger VL, Pellikka PA, Chow CWH, Bell MR, Bailey KR, Seward JB. Sex and test verification bias: impact on the diagnostic value of exercise echocardiography. Circulation 1997;95:405–10.
45. Minnesota Department of Health. Distribution of Insurance Coverage in Minnesota. Health Economics Program, 1996.
46. Jacobsen SJ, Guess HA, Panser L, et al. A population-based study of health care-seeking behavior for treatment of urinary symptoms: the Olmsted County Study of Urinary Symptoms and Health Status Among Men. Arch Fam Med 1993;2:729–35.
47. Manolio TA, Harlan WR. Research on coronary disease in women: political or scientific imperative? Br Heart J 1993;69:1–2.
48. Gillum RF, Feinleib M, Margolis JR, Fabsitz RR, Brasch RC. Community surveillance for cardiovascular disease: the Framingham cardiovascular disease survey. Some methodological problems in the community study of cardiovascular disease. J Chronic Dis 1976;29:289–99.
49. Gillum RF. Community surveillance for cardiovascular disease: methods, problems, applications—a review. J Chronic Dis 1978;31:87–94.
50. The ARIC Investigators. The Atherosclerosis Risk in Communities (ARIC) study: design and objectives. Am J Epidemiol 1989;129:687–702.
51. Goff D Jr, Ramsey DJ, Labarthe DR, Nichaman MZ. Acute myocardial infarction and coronary heart disease mortality among Mexican Americans and non-Hispanic whites in Texas, 1980 through 1989. Ethn Dis 1993;3:64–9.
52. Orencia A, Bailey K, Yawn BP, Kottke TE. Effect of gender on long-term outcome of angina pectoris and myocardial infarction/sudden unexpected death. JAMA 1993;269:2392–7.
53. Verrilli D, Welch HG. The impact of diagnostic testing on therapeutic interventions. JAMA 1996;275:1189–91.